## **LQXB10 Test Report**

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### **Quench Training**

In the first test cycle, MQXB18 quenched at 12959 A (233 T/m<sup>1</sup>). MQXB19 quenched at 12301 (222 T/m), then at 12789 (230 T/m). Following series connection of the magnets, both were ramped to 12208 (220 T/m) and back down.

Quench training results are compared to previous magnets in Fig. 1. Table 1 is a list of quenches executed as part of quench current studies. There was one inadvertent high current quench of MQXB19 after training due to a mistake made ramping during magnetic measurements.

Summary: The requirements for acceptance are satisfied.

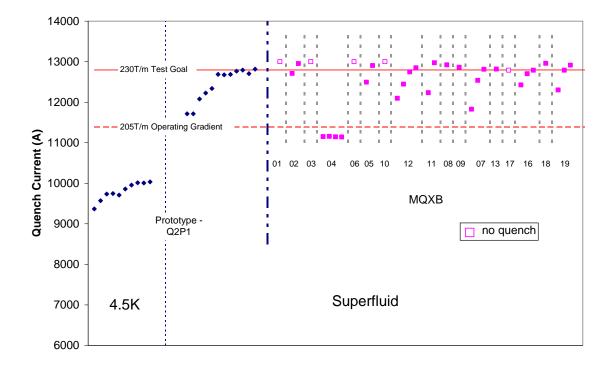


Figure 1: LQXB10 quench training. The horizontal dashed and solid lines correspond to 205 and 230 T/m field gradient respectively.

<sup>&</sup>lt;sup>1</sup>Gradiant quoted is body gradiant based on HGQ09 body transfer function measurements.

**Table 1: List of quenches** 

date	time	test cycle	current (A)	ramp rate (A/s)	location	gradient (T/m) <sup>2</sup>
	MQXB18					
1/12/2006	1711	1	12959	20	Q1	233
	MQXB19					
1/17/2006	1351	1	12301	20	Q2	222
1/17/2006	1455	1	12789	20	Q3	230
1/18/2006	2032	1	12916	20	Q3	232

#### Magnetic Field Quality Measurements

Field quality measurements were made with rotating coils. Integral field measurements were made with a multi-sectioned probe of 3 sections matched to the pitch length of the inner coil with one pitch length between sections. Complete longitudinal scans were made with a probe of length 0.82 m. The program consisted of the following measurement types.

- A "DC loop" in which the magnet was ramped in a series of steps with the field characterized at DC field at each level on the up and down ramp which we use to establish both the upramp and the geometric component of the harmonic. This is done with the integral probe. No such measurement was made as they are redundant with the longitudinal scans with the short probe.
- A prototypical accelerator cycle in which the field was measured during a conditioning pre-cycle to full field followed by a ramp down, a stop at an extended injection porch with a ramp to full field afterwards. This serves to characterize the field at injection including decay and snapback effects. These are typical done with the integral probe; however in these 2 magnets we did cycles with the short probe in the magnet body and in the magnet ends.
- Continuous measurements during a series of ramps to full field and back at different ramp rates to check for eddy current effects. These are done with the integral probe. (Note that the aforementioned accelerator cycle is a 10 A/s loop; 40 and 80 A/s loops were also done.)
- A DC loop with a longitudinal scan at each stopping point. This allows body-end field separation. These scans may be integrated to provide a characterization of the entire magnet.
- A cleansing quench preceded the accelerator cycle measurement with the integral probe.

A list of the measurements made is given in Appendix A. Data is posted at the following URL.

http://wwwtsmtf.fnal.gov/~dimarco/usrAnalysisLQX/web\_summaries/LQXB08/magneticMeasurements/LQXB08\_mag\_meas.html

<sup>&</sup>lt;sup>2</sup> This is the equivalent body gradient based on HGQ09 measurements. The <u>linear fit parameters</u> to the high current transfer function are slope 0.0174 and intercept 7.34.

Tables 2-4 summarize the field quality measurements with respect to the harmonics acceptance criteria<sup>3</sup> for the magnet.

Table 2: Integral Field Harmonics for LQXB10

	LQ		
	669 A	11345 A	
	(12.3 T/m)	(205 T/m)	Unit
TF	0.20210	0.19805	T/A
ML	10.964	10.976	m
FD	0	0	mrad
b3	0.25	0.18	units
b4	0.17	0.15	units
b5	-0.07	-0.03	units
b6	-1.46	0.09	units
b7	0.06	0.03	units
b8	-0.02	-0.01	units
b9	-0.01	-0.02	units
b10	0.02	0.00	units
a3	-1.35	-1.00	units
a4	-0.88	-0.70	units
a5	-0.11	-0.11	units
a6	0.08	0.00	units
a7	-0.02	-0.01	units
a8	-0.06	-0.05	units
a9	-0.01	0.00	units
a10	0.02	0.02	units

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<sup>&</sup>lt;sup>3</sup> Acceptance criteria for harmonics are from <u>v7</u> of the acceptance document. <u>Acceptance bands</u> are from v3.2 of the reference harmonics table. The method for calculation of integral harmonics is given in Appendix D.

Table 3: Integral Field Harmonics for MQXB19

	MQX		
	669 A	11345 A	
	(12.3 T/m)	(205 T/m)	Unit
TF	n.a.	n.a.	T/A
ML	5.483	5.489	m
FD	0	0	mrad
b03	-0.07	-0.08	units
b04	0.34	0.27	units
b05	0.10	0.06	units
b06	-1.40	0.41	units
b07	0.09	0.05	units
b08	-0.01	-0.01	units
ь09	-0.01	-0.03	units
b10	0.03	0.00	units
a03	2.78	2.62	units
a04	0.61	0.60	units
a05	0.46	0.45	units
a06	-0.10	-0.03	units
a07	0.03	0.02	units
a08	0.04	0.05	units
a09	0.02	0.01	units
a10	-0.02	-0.02	units

Table 4: Integral Field Harmonics for MQXB18

	MQX		
	669 A	11345 A	
	(12.3 T/m)	(205 T/m)	Unit
TF	n.a.	n.a.	T/A
ML	5.481	5.487	m
FD	0	0	mrad
b03	0.57	0.44	units
b04	0.01	0.04	units
b05	-0.24	-0.12	units
b06	-1.53	-0.23	units
b07	0.03	0.01	units
b08	-0.03	-0.01	units
ь09	-0.01	-0.01	units
b10	0.01	-0.01	units
a03	0.08	0.63	units
a04	-1.15	-0.80	units
a05	0.24	0.22	units
a06	0.05	-0.04	units
a07	-0.01	0.00	units
a08	-0.08	-0.04	units
a09	0.00	0.01	units
a10	0.02	0.02	units

We see weird hysteretic behavior in MQXB18 (in the unallowed, less hysteretic in the TF at 5460 than usual), but none in MQXB19. We noticed similar hysteretic behavior in the low order unallowed harmonics of MQXB16 and 17. Tables 3 and 4 summarize the situation. One is tempted to blame the strand.

Table 3: Cold masses fabricated listed with inner strand manufacturers

P1	IGC
MQXB01-11	Alsthom
MQXB12-14	Oxford
MQXB15-18	IGC
MQXB19	Teledyne

Table 4: Summary of hysteretic behavior

cold mass	manufacturer	hysteresis in unallowed
MQXB12	Oxford	no
MQXB13	Oxford	no
MQXB14	Oxford	not measured
MQXB15	IGC	not measured
MQXB16	IGC	yes
MQXB17	IGC	yes
MQXB18	IGC	yes
MQXB19	Teledyne	no

The field quality of MQXB19 is the worst we've seen. The skew sextupole is large: 3 units. MQXB18 has more return end structure than usual. The geometric b6 is low in the body, and there is a bigger hysteretic than usual, -0.2 and 1.3 units versus 0.3-0.4 and 1.0-1.1 units respectively in recent cold masses.

**Summary:** Field quality is still decent in the combined magnet. Most harmonics are within one sigma of the target.

## Magnetic Field Strength Measurements

SSW measured integral field strength with magnets powered in series is given in Table 3. The first 4 entries are taken on the up ramp and the last on the down ramp.

*Summary:* The strength at 11345 A is outside the acceptance band of 2254.8 $\pm$ 5.7 [2249.1:2260.5] by 2.3 T; 1.4 $\sigma$  from the expected value.

Table 5: Field strength vs. current.

	integral gradient transfer function (T/kA)	integral field strength(T)	strength TF @ Rref (T.m/A)	B <sub>2</sub> (T.m)
Current (A)	Q2a+Q2b	Q2a+Q2b	Q2a+Q2b	Q2a+Q2b
668.4	202.1	135.1	0.00343570	2.296
5460	200.66	1095.6	0.00341122	18.625
11345	198.05	2246.9	0.00336685	38.197
11922.9	197.75	2357.8	0.00336175	40.082
5460	200.69	1095.8	0.00341173	18.628

## Alignment

LQXB10 had alignment measurements at each stage of testing at MTF: dates are summarized in Table 6. There were also measurements and lug adjustment during mounting of the magnet prior to 03Jan06 to optimize warm alignment before cold test.

The magnet positions experienced quite non-typical changes during the first cooldown – the horizontal position changes of both magnets were on the order of 1mm while changes in the vertical positions were small. The Q2a yaw angle changed somewhat, but Q2b yaw and the pitch angles did not change significantly. The change in the roll angle was about 0.3mrad during initial cool-down, about 0.1mrad of which reversed on warm-up. The cold mass transverse offsets otherwise remained generally closer to their cold values on warm-up.

Strength measurements on the combined Q2a+Q2b were performed at 1.9K.

Adjustments of the lugs were performed after cold testing on the test stand at MTF. The changes from before and after lug adjustment were applied to the MTF cold and warmAft data to generate the final cold and warm RST values.

A partial list of the measurements performed is given in Table 6 with a full list in Appendix B.

Table 6: Major alignment data sets

Warm before TC1	03Jan06
Cold TC1	24Jan06
Warm after TC1	01Feb06
Warm after TC1 Lug	02Feb06
Adjustments	

Data are posted at the following URL.

 $\underline{http://wwwtsmtf.fnal.gov/\sim dimarco/usrAnalysisLQX/LQXB08/SSW/LQXB10\ align.html}$ 

Relative alignment of the magnet assemblies compared to AP requirements is given in Table 7. The relative alignment is similar to the last couple of magnets. There is more relative roll than in LQXB08 and 09.

Table 7: Relative alignment of magnet assemblies (cold).

relative al	relative alignment				
Q2a/Q2b					
transverse			х	у	
alignment	500	μm	-1913	-287	
Q2a/Q2b					
relative roll	1	mrad (rms)	-0.	.43	
Q2a/Q2b					
relative pitch	0.1	mrad	-0.	.39	
Q2a/Q2b					
relative yaw 0.1 mrad		0.25			
relative alignn	relative alignment of MCBX to Q2				
corrector					
displace-					
ment	500	μm	n.	a.	
corrector roll	5	mrad			
B1 (hor.)			-2.	.20	
A1 (vertical)			-0.	45	

LQXB10 Alignment: Q2a Q2b Axes wrt Magnet Fiducials 24Jan06 Axis

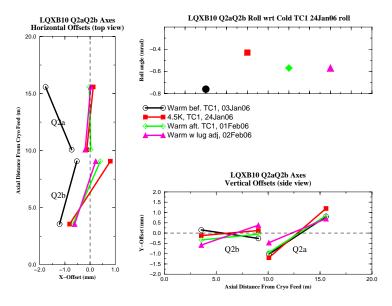


Figure 2: Alignment summary plot.

A summary plot showing the changes in cold mass positions at various points in testing is shown in Fig. 2. The positions are given relative to the Cold TC1 measurements being on the average axis.

Summary: Non-standard changes were seen horizontally and vertically in the cold masses during cooldown with the cold masses remaining close to their cold positions

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after the thermal cycle. The movement was largely horizontal and had very little vertical movement, whereas in previous magnets, there was typically ~0.5mm vertical motion. Lug adjustment was performed afterwards to maintain the best cold alignment. There was a change in roll during cooldown of about 0.3mrad which reversed by about 0.1mm on warm-up.

Other tests performed

Other items of interest

# Appendix A: List of field quality measurements

Note that a longitudinal scan of the magnetic field with a rotating coil of the warm collered coil and cold mass were made during production as part of the quality assurance program but are not listed here.

q2a	MQXB19			
size of the	date of		probe (IP=integral;	
unpacked file	measurement	file name (unpacked file)	sp=short)	remarks
21606584	1/20/2006 18:10	q2a_accprofile_short.odb	IP	accelerator profile
18394376	1/18/2006 15:27	q2a_loop40As.odb	IP	40 A/s loops
11778256	1/18/2006 15:50	q2a_loop80As.odb	IP	80 A/s loops
8000760	1/20/2006 16:12	q2a_11345do.odb	S D	z scan 11345 down
8909760		·		
	1/20/2006 17:16			z scan 11345 up z scan 11922
	1/20/2006 17:10			z scan 5459 do
		· -		
	1/18/2006 18:07	q2a_5459up.odb		z scan 5459 up
	1/18/2006 17:36	· – ·		z scan 669 up
21606584	1/20/2006 18:10	q2a_accprofile_short.odb	SP	accelerator profile
01	MOVD40			
q2b	MQXB18		1 (ID :	
size of the	date of	(n)	probe (IP=integral;	
	measurement	file name (unpacked file)	sp=short)	remarks
	1/13/2006 16:02	q2b_accProfile.odb		accelerator pofile
	1/13/2006 16:27	q2b_loop40As.odb		40 A/s loops
10580928	1/13/2006 16:51	q2b_loop80As.odb	IP	80 A/s loops
	1/13/2006 19:23	q2b_11345up.odb		z scan 11345 up
9008576	1/13/2006 19:53	q2b_11922.odb		z scan 11922
	1/13/2006 20:19	q2b_5449do.odb		z scan 5459 do
	1/13/2006 18:52	q2b_5449up.odb		z scan 5459 up
9270728		· - ·		z scan 669 up
4078312	1/13/2006 20:29	q2b_accprofile_short.odb	SP	accelerator profile

### Appendix B: List of alignment measurements

tbc

### Appendix C: Q2A/Q2B->MQXB19/MQXB18

Inside LQXB10, Q2A, closest to the MTF return can, the CDF side of the building, is MQXB19. Q2B, closest to the MTF feed can, away from CDF, is MQXB18.

## Appendix D: Calculation of Integral Field Harmonics

Integral field harmonics are computed from the data taken during the longitudinal scan of the magnets as described in earlier reports.

### Appendix E: Calculation of Magnetic Length

Magnetic lengths were calculated from rotating coil data as described in earlier reports.